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Stope Books

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STOPE BOOKS.

Methods for Keeping Precise Records of Stopes—Their Form, Volume, and Location.

A Description of the Most Suitable Form of Book and Illustrations of the Manner of Recording the Variations Due to the Various Methods of Working and Timbering.

Written for MINES AND MINERALS by Joseph Barrell, E. M., M. S.

In large metal mines, where the veins are more or less vertical and great volumes of ore are extracted from between the levels, it becomes important to adopt such a system for recording the shape and location of the stopes that at any future time the engineers may be able to give precise information concerning them, without entering the mine for the purpose.

The drifts are really but a very small portion of such a mine, and to give anything like a complete representation, some method of surveying the intermediate portions must be devised. To attempt to carry a transit survey around their boundaries would result in great labor and no real gain in accuracy, but where a regular system of timbering is employed this can always be utilized, and the records of the stope work can be easily and accurately kept. The office of the transit survey is to act as a control over the whole mine, and its relation to the sketches of the workings is similar to that between the primary triangulation and topographic sketching of geodetic work.

The location of the stope sketches will be given by showing in them the transit points, and the sketches themselves will be a systematic series of sections through the vein determined by lines of timbering.

Such methods are more or less commonly in vogue in the western mining districts, the sketches of the stopes being kept in books of cross-section paper. But there are all degrees of perfection in the manner of doing this, from crude, unplaced sketches to a method so complete that from it a carpenter is able to make an accurate model of the stopes without having been in the mine. The very exact and simple way in which this end was achieved is due to A. A. Abbott, E. M., mining engineer for the Boston & Montana Co., aided by discussions with Mr. C. S. Batterman, superintendent for the same. While the credit for whatever is of value is entirely theirs, the writer is responsible for the following discussion and the conclusions may not be always those to which they would subscribe.

In order to understand the nature of the problem a few paragraphs will be devoted to the character of the mines, and then will follow the method of keeping the stope books. In other mines, where the system of timbering is irregular, and especially where stulls are used, wide variations in the methods of keeping stope books are inevitable; such can best be discussed after the type method has been explained.

Butte Methods of Mining.—The methods of mining in Butte vary from the "gophering" of the leaser working on a scantily paying silver vein, whose mine may resemble an irregular burrow with but a few sticks of timber, to the great copper properties where prospecting is done years ahead of the demand, and hundreds of tons of ore are taken from each shaft per day. Our subject deals especially with the latter class and it is to them that the descriptions refer.

Stations are cut from the shaft at every hundred feet in depth and prospecting and development work consist in driving crosscuts to intersect whatever veins may lie within the property. Drifts are opened along those which are promising.

The ground is usually firm enough so that there is no necessity for keeping the timbering close to the face, but before any overhead work is done the drifts are completely timbered with square sets. The veins vary from innumerable mere cracks and splits in the zones of shattered rock to those from 10 to 150 feet in width. The wider ore deposits are not entirely true vein material, but are more commonly two closely parallel veins, or at other times, veins with widely impregnated walls. The streaks of barren rock, when narrow, are broken down and used as filling for the stopes. The width of the stopes and the amount left as waste thus depends, to a great extent, upon the state of the market and the cost of working. The old stopes soon become more or less inaccessible, and from all these conditions the advantage of keeping complete records of the work done is evident.

The Butte copper deposits are sulphide ores lying in veins, with a general east and west trend, in a highly mineralized area not more than 3 miles long by 2 miles wide. The copper is restricted, at least within the depth explored up to the present time, to the eastern central part. The enclosing rock is a basic granite, an immense intrusive mass of considerable scientific interest, extending perhaps 45 miles north and south, and 20 miles east and west. These general features must, however, be quickly passed by.

Where the drifts have passed through workable ore, upraises are driven from them, two or three sets in width, on the foot-wall, to the level above at intervals along the drift of from 200 to 500 feet, cutting the vein up into blocks. The work of stoping proceeds horizontally from the raises, the lower floors being worked first and timbered as the work proceeds. Thus the timbering of each floor rests upon that of the one below.

At intervals of from 50 to 80 feet chutes are built by merely boxing in the chute-set with 2-inch planks, and where the ore is separated into two grades they may be sent down separate chutes to the level. The chutes are carried up along the foot-wall to be as free as possible from the effects of settling, and consequently,

must step off from set to set according to the dip. They do not, however, step off along the strike, and thus they furnish a convenient means of locating each floor with respect to those above and below. Figs. 2, 3, 4, and 5 show the general method of working just described. Large stopes should not be left open long and the filling of waste rock is usually kept up to the chute nearest the face. In this way there is a manway and chute leading to each floor besides a passageway by which one can climb from floor to floor along the face of ore. The rock filling crumbles and becomes compact in a year or two, and, taking up the pressure as the timbers decay, prevents extensive caving.

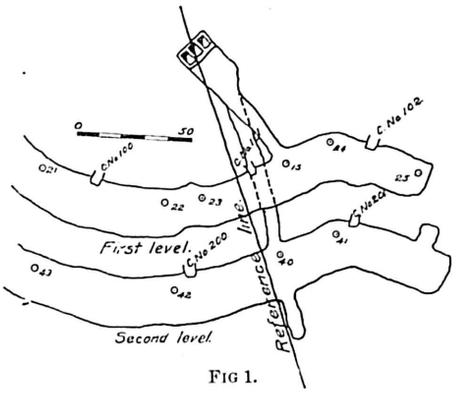

Fig 1.

Timbering.—The timbering is entirely by square sets of 10-inch timber. The lengths of the timbers vary somewhat in different mines, but in any one mine an exact system is used, the timbers being cut ahead of the demand by the carpenters at the surface, and in the mine are set up and leveled by timbermen whose sole work it is to attend to that duty. Thus, in a steep wide vein a line of posts may reach from level to level, locating points in the same perpendicular with almost the accuracy of a plumb-line. The timbers are always cut one set long and the manner of joining is of some moment. The posts on the drift should be about 7 ft. 10 in., center to center, to allow for doubling the cap in future years without reducing the height in the clear to less than 6 feet. As the stopes are filled before decay begins that reason does not apply to them. After locating on the levels the raises and chutes, the timbers furnish us with a series of perpendiculars and offsets by which each floor can be sketched, and any point in it located with respect to the transit survey on the drift below. The value of such accurate and permanent records can be easily seen. They enable the superintendent to note the amount of ore extracted each month, and the size of the ore reserves; the engineer to construct maps of any part of the stopes with the same accuracy as those of the drifts. The foreman has a means of locating any blocks of low-grade ore, and going back to them in after years, and lastly, the sampler, by noting the set from which his samples are taken, is able to record both the value and volume of the ore.

Preparation of the Stope Book.—Although it is seen from the above that the timbering furnishes the means for sketching and locating the stopes, some regular system must be followed or inextricable confusion will result. The book must connect the stope sketches with the transit work of the drifts and also the various floors with one another. In it there must be a place for everything and everything must be in its place.

To illustrate by examples and make clear the following discussions Fig. 1 is given, a hypothetical map of a portion of two levels, so drawn as to involve the greater number of the points in question; Figs. 2, 3, and 4, follow from it, Fig. 2 being one leaf from the stope book. The paper should be of the quality of that used in field books, ruled by the printer vertically and horizontally, with waterproof lines in a colored ink, preferably green. A convenient scale has been found to be 4 lines to the inch, every fourth or fifth line to be heavier. Each square will represent a square set, giving an actual scale of about 20 feet to the inch. A smaller scale does not show enough detail and a larger one is not necessary for this class of work.

The most convenient size for the bound books is 11 inches long by 5½ inches wide. They can then be carried in an inside coat pocket and kept clean from mine dirt and water while climbing. Only the right-hand leaves are numbered, so that when open a page extends entirely across the book, 20 inches, showing 400 feet of the length of the vein and wide enough for two floors on one page. The floors immediately above each other must follow on consecutive pages; thus, on the first double page will be 400 feet of the sill floor and first floor, on the second page the second and third floors, and on the seventh page the twelfth and thirteenth floors. The eighth page is reserved for cross-sections of the vein, and the ninth for the long upright section, these two being shown by Figs. 3 and 4. The next 400 feet of the same drift will be shown on page 10, so that it joins on to page 1 on one side and to page 19 on the other, and in this way the work of one level is kept together. For convenience the book should be indexed by placing a projecting tag with the number of the level on each page of the drift floor.

Having now a general idea of the arrangement of the work in the book, it remains for us to determine, precisely, how to place it and how to show the relation to the transit surveys. First, it is necessary to have some reference line on the vein. For this purpose draw on the map, through the center of the shaft, a line perpendicular to the strike of the vein, as shown in Fig. 1. Scale off from the map the distance at which it cuts the transit course from the nearest station. Then, by adding the known distances between stations to this, we obtain the surveyed distance of any point on the drift from our reference line. Select the middle or end of a page in the stope book for the zero or reference line, such that the drift will go most conveniently in the book, and on the upper line locate the survey points at their proper distances from it, as in Fig. 2. The advantage of using a reference line is not so much to obtain a starting point on one level as to coördinate the different levels, as shown in the final long section. The vertical location of any part can be told when the dimensions of the timbering are known. In this instance the drift is 7 ft. 10 in. high, and each of the following 12 floors are 7 ft. 2 in. If the levels are exactly 100 feet apart the thirteenth floor will consequently be 6 ft. 2 in. in height.

The Stope Book in the Mine.—Having indicated in the office, by a regular system, the place for everything which we will find in the mine, the next step is to proceed to the details of sketching. The location of the stations on the top line of the drift-floor pages shows on what vertical line they should lie in the sketch, but the fact that each square must be kept as representing a square set, and that any or all of them may not be exactly to our scale, will cause the location made in the mine to vary slightly from that made in the office. Any such discrepancy must be taken upon the edge of the page. Therefore, proceed to the station nearest the center of the page and locate it as nearly as possible under its position at the top, remembering that the sets of timber, no matter how irregular, must be represented as squares. Now walk along the drift watching the character of *one* side at the line of the *floor*, sketching while walking, counting the sets and indicating the posts by dots of the pencil. Check up the number of sets on each station and continue to the end of the drift. Sketch the other side in coming back, and by counting the sets a second time, from station to station, a further check is placed upon the work. On the correctness of the sketches of the drift floor that of the overlying stopes depends.

Having finished the drift, climb to the first floor and locate the set climbed through, the same distance east or west of the reference line as on the drift below, see Fig. 2. Since the chutes and manways will ordinarily not step off sideways, but only along the dip, a chute will be represented the same distance from the side edge of a page on all those floors where it occurs. In this way each floor is located in longitude. To do the same in latitude it will be necessary to give an arbitrary number to that row of timbers on the ground floor against the hanging wall. It is well to start with 10, since then, on a wider working of the hanging wall there will be no danger of running down into negative numbers. The rows are numbered, consecutively, as they step off toward the foot-wall. Thus in Fig. 2, on the drift floor, the manway to chute No. 102 is in row 14 and that determines

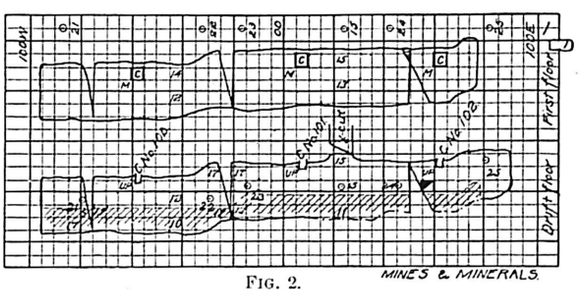

Fig. 2.

the numbering on the first floor. On the thirteenth floor, in this instance, as shown in Fig. 3, the manway is in row 19. In such a manner each floor is completely located with reference to the drift below and ultimately with the transit survey.

The ease and rapidity of the work will depend upon the character of the mine. Much is gained by practice, the work not being sketched set by set, but a pause for sketching being made every fifth or tenth set, or wherever there is a change in the character of the wall. In drifts such as are usually found, from 3,000 to 8,000 feet of sketching is a good day's work. The sketch should be taken at some definite horizon, and that of the floor level is best. Features of constant recurrence must be represented by conventional signs. Thus, in Fig. 2, *c* enclosed by a square

indicates a chute passing through the floor; *up* means a ladder *up*; *M*, a manway down. A full line indicates a rock wall, a broken line, lagging; cross-hatching represents filling; a dashed and dotted line, the presumed limit of filled workings, etc. It is of importance to indicate irregularities in the timbers. If it is a short set write *S* within the square, if a long set *L*, giving the length if necessary. If there should be an angle in the timbering so that there may be a set more on one side of the drift than on the other, represent it by a wedge-shaped opening, as shown, being the appearance of the drift if it were straightened out. In sketching it is essential to accuracy that the attention be held to a few things at a time. On reaching the top of the raise the plan views are completed, each floor having been sketched on the way up. On descending, turn to page 8 and sketch the cross-section of the manway, as shown in Fig. 3. Each set is still represented by a square, although the sets are higher than wide, but since that fact is known it can lead to no error.

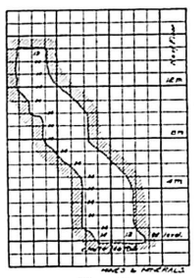

Fig. 3.

The stope book is taken through the mine and brought up to date at the first of each month, and it is necessary for the foreman or shift boss to accompany the engineer and point out each place where work has been done. To pick up the work readily and identify the last set of the previous month, the last cap should have a notch cut in it and the same indicated in the book.

The Long Section.—The view of the vein which will be of most general use and show at a glance the progress of the work of ore extraction is the long section. It is a modified vertical projection of the vein, such as would be obtained if the rock on the hanging-wall side should be removed and the vein viewed from a distant standpoint at the same level. Fig. 4 shows the final section made in the office to the same scale as the map, but each part of it for the corresponding 400 feet of a level will be placed on pages 10, 19, etc. of the stope book, and is compiled from the sketches of each floor. The long sections can be drawn from the plan views of the floors either in the mine or the office, but it is a little better to determine the *limiting* points in the mine. The transit stations, chutes, and raises should, of course, be located upon it as common points with the map, connecting the two. The final long section is drawn by merely piecing together the several parts from the stope book and drawing them horizontally and vertically to the same scale.

Since the vein, however, is quite an irregular surface, the question arises as to what modification of a vertical projection will give the most accurate and convenient representation of the vein. That devised by Mr. A. A. Abbott is shown in Fig. 4, of which the essential feature is the horizontal adjustment space left between the levels. At our reference line, in this case the projection of the shaft upon the vein, the zero points of the levels are placed over each other. But owing to the warpings in the vein a raise such as No. 201 started, in this case, 40 feet east will not break through on the similar point of the level above. The simplest way in which to allow for these discrepancies, is to draw the levels more than their true distance apart by the width of an adjustment space, lay out each level at its true length and draw the raises perpendicular to them, providing, of course, that the raises only step off along the dip and not along the strike. All these features can be appreciated by studying Figs. 1, 2, 3, and 4 in connection with each other. Lines corresponding to the height are ruled on the sides of the drawing, and the floor on which the work is being done is ascertained by means of a parallel ruler. Such a view approximates to a *development* of the vein horizontally, but vertically to a *projection*, since the vein is projected on a series of vertical planes passing through the transit courses. The drifts are shown at their true length, but the heights are the vertical distances and not the lengths up the dip.

The long section will be brought up to date every 3 or 6 months, and the portions of the vein extracted during the interval indicated by cross-hatching or tinting. In the illustration the ore bodies are cross-hatched to bring them out more clearly, but to do this on the regular map would involve erasures with every extension in the workings. In the mine a hard and sharp drafting pencil will be used, but pencil markings in a book constantly in use soon become faint and blurred. It is necessary to go through the book at intervals and ink in everything with waterproof drawing ink. Two colors can be used with advantage, red for all transit lines and survey figures, black for the stopes and those symbols relating to them. If there are several splits to a vein, sometimes worked together and sometimes not, the work on the different splits can be readily distinguished on the *long section* by using red for the hanging-wall split, and blue for that of the foot-wall. If old filling is taken out, such as ore, as frequently happens, the parts extracted can be cross-hatched in red, and thus a record of both the first and second extractions preserved.

Variations in Preparing Books.—Having now considered, in its entirety, a method which has been found the best for a certain type of mine, we can discuss variations suited to other conditions without confusing the whole subject. The *reference line* must be perpendicular to the strike of the vein to be of any value in coördinating the several levels. It is best to place it upon the map and to pass it through some natural object in order to give it a fixity and a permanence. As the shaft is usually near the center of the property and the workings start from it, it offers the best fixed point, and reference lines may be drawn through it, one to each vein worked. If, however, the shaft should be far to one side, and the surface of the vein much flexed, the adjustments in the long section between the levels may become so great that a reference line through some point more in the center of the property would be advisable.

The next subject for consideration is the method of measuring the distances along the drifts, the end in view being to get the nearest approximation to the true length of the vein. In some of the immensely thick ore bodies of Butte, and similarly, in massive bodies of iron ore, the drift may be quite crooked and ramble in the vein with here and there short crosscuts. In such a case the sum of the transit courses would give an undue length to the vein. A better way, then, is to draw a base line on the map which shall be parallel to the course of the vein. It should be drawn to one side of the latter and composed of straight lines, with angles where necessary, to follow the changes in direction. This broken base line corresponds to what would have been the transit courses on a drift following the vein walls, but will consist of much longer courses. Distances along the vein are obtained by projecting the transit points upon the base line and scaling off the projected length of the courses. These are entered at the top of the stope book and determine the location of the stopes in the book. A separate base line may have to be drawn for each level, owing to changes in the curvature of the vein. They must be permanent lines and are best kept on a separate tracing. Such a method is more artificial and cumbersome than that of using the transit courses for base lines, and is only of advantage where drifts are so irregular that they are appreciably longer than the vein. The way in which the floors and sections of the vein follow each other in the book may be varied. The one described

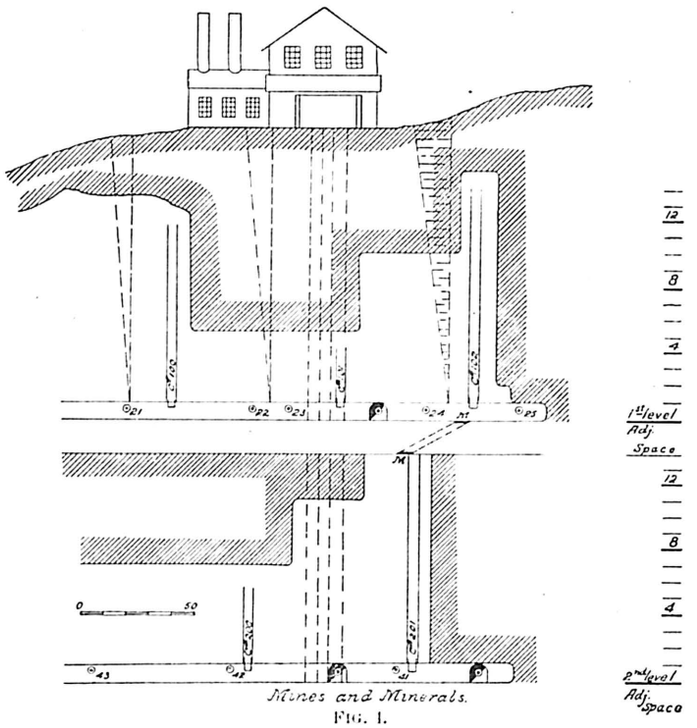

Fig. 1.

was chosen for description as being the easiest to comprehend, and if adhered to, is as good as any other, but those which the writer has used were somewhat different.

Variations Due to Timbering.—The discrepancies due to irregular sets have been already spoken of and can lead to no error, since their positions and amount are shown by the location of the transit points on the top lines of the stope book, and the notes made on the sketches. In most examples of square-set timbering, the line of timbers is carried forward parallel to itself, and where the vein offsets, the timbers step off instead of changing the direction of the caps and girths, but where a decided change takes place in the course of the vein, a corresponding

change is made in the timbering, and the angles are quantitatively shown by the device already alluded to. In veins one set wide, however, it is more economical, especially if the ore be poor, to let the line of timbers swing with all changes in the vein by means of cutting one girth longer than the other. In such cases the convention may still be employed, and even when the girths are omitted and only caps and posts used, the conventional mark may be retained though no longer of quantitative value. To get an idea of the bends in drifts and stopes imperfectly timbered, a pocketfull of candle butts should always be carried. By placing lighted butts at reference points, and by the side of posts, the line can be accurately carried as far as they are visible. In the stopes all degrees of timbering may be found from the irregular stulls, characteristic of workings in narrow veins, to the precise system of square sets used in larger properties. The drifts may be sketched with accuracy in any event, but in the stopes the case is different. Considering first that of irregular stulls, it is seen there are no longer definite floors and the horizontal sections must as a rule be abandoned. In the ladderways and raises we still have tolerably definite lines, and with a tape and clinometer transverse sections can be made, showing the dip and width of the vein. The long section can be obtained in the same way by measuring out from the ladderway, horizontally, and taking offsets vertically. In such narrow veins, complete horizontal sections every 7 feet would be entirely unnecessary, and so much space need not be left for them in the book.

Systems of Timbering Disconnected From Drifts.—It is not uncommon to find old prospecting raises, or those reopened through old filling, timbered with inclined sets whose dip varies with that of the bed. At intervals on the sides, or above the old filling, stopes are opened and timbered with the usual square sets. To locate the horizontal and vertical position of the floor with accuracy, the writer has employed the following method as being the simplest: A lighted butt is placed in the corner of the timbers at every angle in the dip. The sets are counted and sketched on an extra sheet of cross-section paper on the way up; a nail is driven in at the top in a protected and permanent place and the end of the tape hung over it. On the way down the distances are measured to each angle and the inclination of the timbers taken by a clinometer. On this day only the drifts and raises are sketched, since we do not yet know where to place the stopes in the book. On returning to the office, rule a sheet of paper with horizontal and vertical lines to the true proportions of the square sets used in that mine. Lay off on this by protractor and scale the data obtained in the mine, and the number and location of any floor at once becomes evident. Transfer this by means of the cross-section lines, without the aid of instruments, to the page in the stope book for transverse sections. The vertical scale becomes somewhat reduced, since, in the stope book, the cross-section lines form squares. Then have stamped, at the blacksmith shop, on copper tags, numbers running as high as the number of floors and we are ready for the mine again. In climbing up the raise, the page of transverse sections shows us at which inclined sets to stop and nail fast a copper tag opposite the level of its corresponding floor, leaving a permanent reference to the work in the mine. We can now identify the floors, sketch them in their proper places, and insert the conventional number showing the number of sets stepped off from the drift below. Such a method is not laborious although the work is divided among several days.

In localities of contact or impregnation ore deposits the ore bodies may be of considerable size and of irregular shape and occurrence. It is particularly desirable to have accurate stope notes, of such, but here again, the timbering may be disconnected from the drifts. In Leadville, Col., such ore bodies lie in limestone near the contacts with porphyry. To escape, to a certain extent, the great volumes of water with which the limestone is charged and also to have the levels below the ore bodies, they may be driven in the porphyry and vertical raises made at intervals to tap the ore. In order to get the line of timbers and to determine connecting points the writer understands that a couple of wires are put in the raise and the lines carried up by plumbing. For such work it may not be necessary to use the more elaborate methods of plumbing, it sufficing to set the instrument up a few feet from the wires and measure angles and distances to them and between them. In this connection it is worthy of remark that wherever, through a mine, it is convenient to carry a survey line by plumbing for distances of 100 feet or less, especially in dry or quiet places, it is very convenient and accurate to use an idea suggested to the writer by Mr F. T. Greene, E. M., namely, that of a pocket plumbing outfit. A couple of hundred feet of No. 32 wire can be purchased on thread spools for a few cents. They are weighted with light weights and each suspended in a dinner bucket of water.

Methods of Constructing the Long Section.—Two radically different ways of constructing the long section suggest themselves, viz.: by projection upon one or more planes and by a development or flattening out. That which has been described is a combination of the two, and its advantages over either alone are so evident that but little time need be spent discussing the reasons. According to the straightness of the vein it approximates to a projection upon a single plane, but if a single plane were used for crooked veins, those parts at an angle to the vein would be foreshortened by projection. If, in addition, it should be sought to incline the plane of projection to the dip of the vein, in order to show the area more accurately, the complications would become unmanageable in square-set work since all the floors and posts would be at an angle to the plane. Even in narrow stulled veins there would not appear to be any advantage over keeping the plane of projection vertical, and if more than one plane were used it would be out of the question. If, on the other hand, a method of development should be attempted without leaving adjustment spaces between the levels, a lack of adjustment between two levels would affect all the rest and the problem of representing a warped vein on a plane surface would become a difficult one. Since those variations have been thought over and abandoned it is hardly worth the space to discuss them more fully. There remain, however, a couple of features in connection with the adopted method which need mention. First, *where the line of timbering is not exactly parallel to the transit or base line* the caps are not projected exactly end on, and the posts in a single tier are not exactly hidden behind each other. Consequently, the raises in stepping from set to set in passing up the dip would be theoretically projected as slightly inclined one way or the other. But this is ordinarily so slight that it is best disregarded. If, however, the raise should run decidedly obliquely up the vein, judgement may require that it be located in that manner on the long section. Second, *where the line of timbers changes*, as at several places in Fig. 2, the number of sets between two chutes will increase on the upper floors if the vein is concave toward the hanging wall, and will decrease if convex. This will show in the long section, as a triangular overlap in the first case, and as a triangular vacant space in the second, as shown in the figure. In an accurate computation of the volumes of ore taken out and that remaining, there should be an addition corresponding to areas of the first kind, and a subtraction of the volumes of the vacant spaces.

Accuracy and Uses of the Method.—The value of these methods over mere sketches made without system lies in their accuracy. Where the timbering is irregular the accuracy of the results will depend chiefly upon the time and care taken in the work; a tape line and clinometer may be needed to supplement the timbering and give over all measurements. Where a mine is worked by a company and the usual care taken in timbering, the work can be carried from level to level so precisely that on checking it up on maps drawn to a scale of 50 feet per inch, no error is observable. Where square sets are used it is seen that the system consists in making sections at regular intervals parallel to the three coördinate planes. In exploring old workings a stope book leads one into every possible place, and on coming back, one has exact notes on the place with a completeness which could not be got in any other way. They will often bring out features in the structure of the ore bodies which had been previously unnoticed and lead to crosscutting at certain points in search for ore. They show the property lines on each floor and, if desirable, models of the vein could be made from them. Perhaps one of the chief values is for computing the volume and value of the ore remaining. In that part of the mine which is developed the vein will be cut up into blocks, the four edges of which are accessible. With the form shown in the stope books a close approximation to the volume can be made, and by sampling across the face, at frequent intervals, the value can be told also.

The neatness of the work makes it a pleasure, and the writer has never enjoyed underground life more than when, with a stope book, exploring alone the silence and darkness of abandoned workings.

The following prices are given by the United States Geological Survey as those by which sales of iron were made early in 1899 for season delivery:

Mesabi Bessemer	$2.25	@	$2.40
Mesabi non-Bessemer	1.90	@	2.10
Marquette specular No. 1, Bessemer	3.21	@	3.50
Marquette specular No. 1, non-Bessemer			2.50
Chapin			2.73½
Soft hematites No. 1, non-Bessemer	2.00	@	2.15
Gogebic, Marquette, and Menominee No. 1, Bessemer hematites	2.80	@	3.25
Minnesota No. 1, hard Bessemer			3.58
Minnesota No. 1, hard non-Bessemer			2.65
Chandler No. 1, Bessemer			3.35
Marquette, extra low Phos. Bessemer	3.85	@	3.90

The bulk of this ore was sold in January and since that time advance has been made of from 50 to 75 cents per ton over the prices given.